CHAPTER 2

LIQUID-COOLING SYSTEMS

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Identify the different types of liquid-cooling systems for electronic fire-control equipment.
2. Identify the components for the liquid-cooling systems.
3. Identify the maintenance responsibilities for the liquid-cooling systems used by Fire Controlmen.

INTRODUCTION

Cooling systems are essential to the satisfactory operation of a shipboard weapons system. In fact, some form of cooling is required for all shipboard electronic equipment, and liquid cooling is especially efficient for the transfer of large amounts of heat. To maintain cooling systems, you must have a broad understanding of the different types of liquid-cooling systems with which you are involved. As a Fire Controlman, and because you operate and maintain electrical and electronic equipment, you are required to have a thorough knowledge of liquid-cooling systems.

This chapter discusses basic liquid-cooling systems, liquid-cooling systems configurations, and liquid-cooling systems for the Mk 92 fire-control system (FCS). It also discusses the maintenance responsibilities you have as a Fire Controlman for these systems. For more detailed information on these and other cooling systems, consult your applicable operating procedures and *Basic Liquid Cooling Systems for Shipboard Electronics,* NAVSEA 0948-LP-122-8010.

BASIC LIQUID-COOLING SYSTEMS

The typical liquid-cooling system is composed of two basic cooling systems: primary and secondary. These two systems are discussed briefly in this section.

PRIMARY LIQUID-COOLING SYSTEM

The primary liquid-cooling system provides the initial source of cooling water that can be either seawater or chilled water from the ship's air-conditioning plant, or a combination of both. Figures 2-1, 2-2, and 2-3 show the basic arrangement of liquid-cooling systems that use seawater and chilled water. You are encouraged to refer to these three figures as you study this chapter.

In figure 2-1, seawater from a sea connection is pumped by a seawater circulating pump in one of the ship's engineering spaces through a duplex strainer to remove all debris and then is pumped through the tubes of a heat exchanger. Finally, the seawater is discharged back into the sea at an overboard discharge.

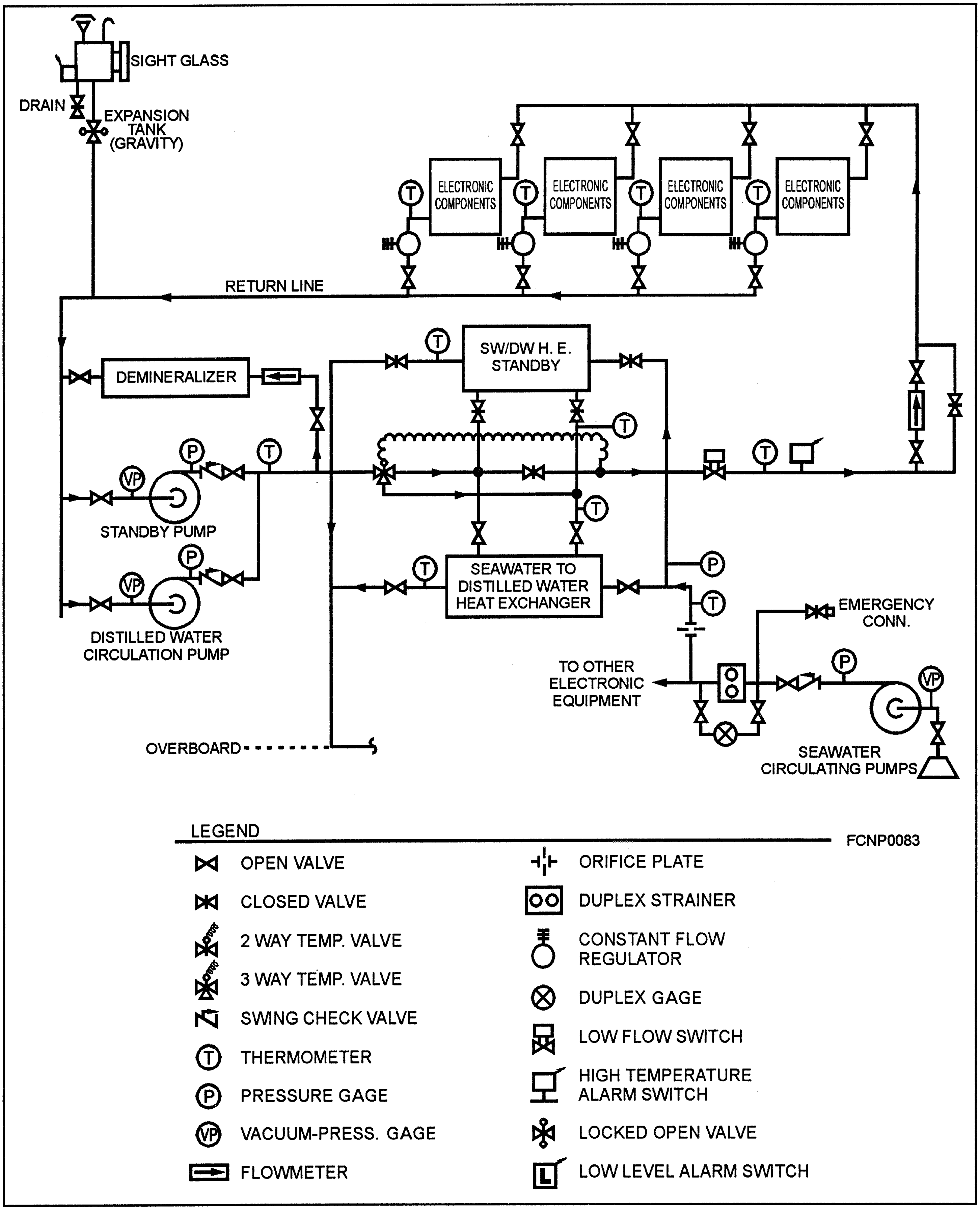

Figure 2-1.—Type I liquid-cooling system.

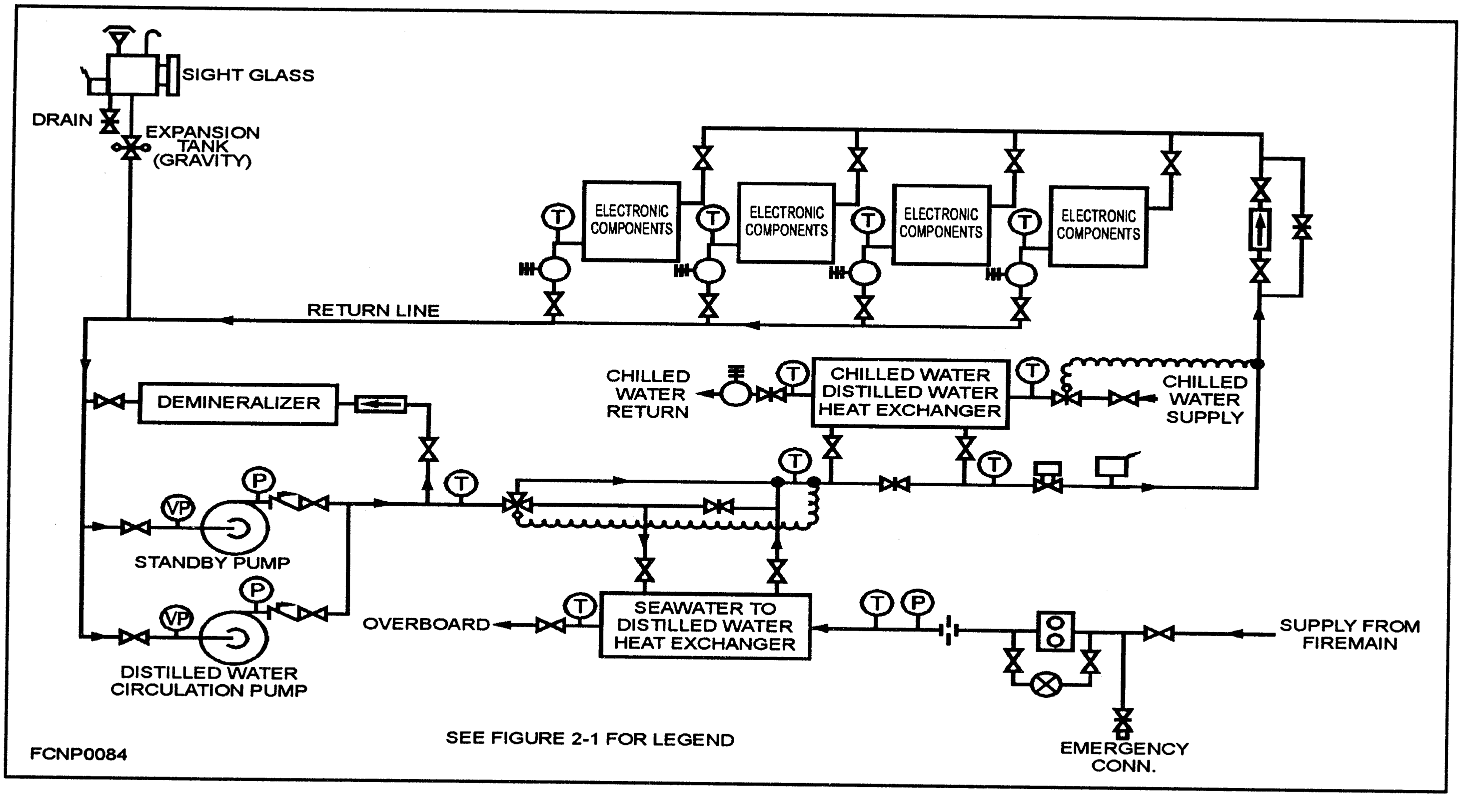

Figure 2-2.—Type II liquid-cooling system.

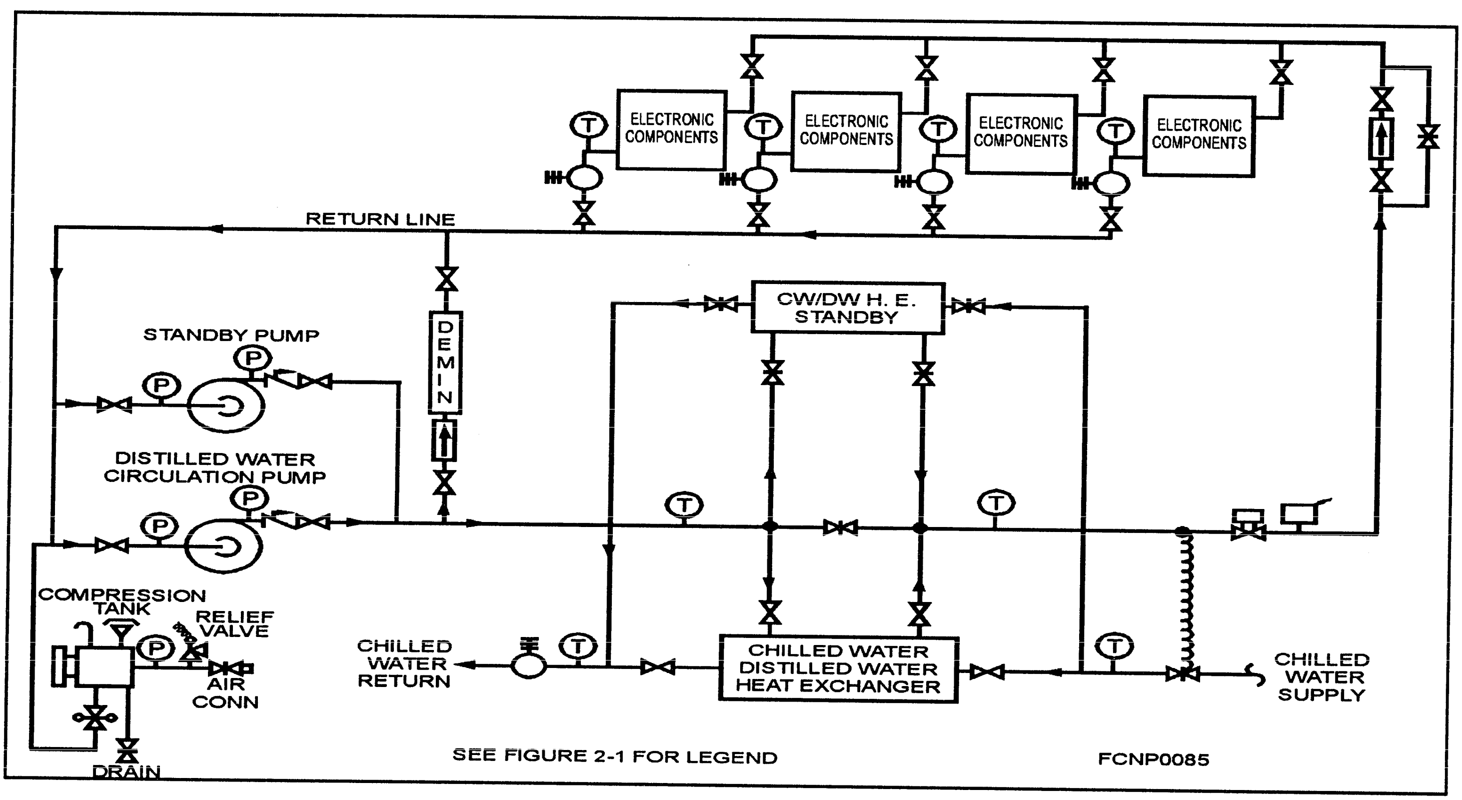

Figure 2-3.—Type III liquid-cooling system.

The seawater system shown in figure 2-1 is a multiple-branch system. As such, it supplies a number of heat exchangers for other electronic equipment. To regulate the proper amount of seawater to each cooling system, an orifice plate is installed in the line between each heat exchanger and the duplex strainer. The heat exchangers are referred to as *seawater-to-distilled-water heat exchangers.*

Another means of providing seawater is through the ship's fire main, as shown in figure 2-2. The seawater is taken from the fire main through a duplex strainer and a flow regulator (orifice plate) to and through the heat exchanger. It is then discharged overboard. The connection to the fire main is permanent.

The ship's fire pump, not shown in figure 2-3, is used to pump seawater into the fire main. The fire pump is similar in design to the previously mentioned seawater circulating pump, except it has a much larger capacity.

Another means of obtaining seawater as a primary coolant for types I and II liquid-cooling systems is by an emergency connection, which is used if the normal seawater supply is lost. The connection is usually by means of a 1 1/2-inch fire hose. The emergency supply comes from an alternate portion of the ship's fire main or a portable pump rigged by the ship's damage control party. The portable emergency hose is normally stored in the liquid-coolant machinery room.

In types II and III liquid-cooling systems, chilled water is taken from the supply main of the air-conditioning, chilled-water systems. The chilled water is used as a backup source of cooling water for the primary cooling system shown in figure 2-2, and as a normal and backup source for the system shown in figure 2-3. The chilled water flows through the tubes of the heat exchanger (chilled water to distilled water), a flow regulator, and back to the chilled-water system. A temperature-regulating valve at the inlet of the heat exchanger regulates the flow of chilled water through the heat exchanger to maintain the required water temperature in the secondary system (distilled water).

The ship's air-conditioning, chilled-water circulating pump is used to pump the chilled water through the heat exchanger. The chilled-water system is a closed-loop water system because the water is recirculated. The system must be kept tight and free from leaks to ensure satisfactory operation.

SECONDARY LIQUID-COOLING SYSTEM

The secondary liquid-cooling system transfers heat from the electronic equipment being cooled to the primary cooling system. The coolant normally used in the secondary system is distilled water, which is ultrapure and is maintained in that state by a demineralize. In some secondary systems, ethylene glycol is added to the water to prevent freezing when the system is exposed to freezing weather.

The secondary liquid-cooling system is usually comprised of a distilled-water circulating pump, a compression or gravity-feed expansion tank, the electronic equipment being cooled, a demineralizer, a temperature-control valve, the monitoring equipment with its associated alarms, and the heat exchanger, which is shared with the primary system. The secondary system is a closed-loop water system, as compared to the seawater system, which is a one-pass, or open-loop, system.

LIQUID-COOLING SYSTEM CONFIGURATIONS

The U.S. Navy uses three basic configurations of liquid-cooling systems, and you could be involved with all three of them, depending on the number and types of electronic equipment to be cooled. The specifications for the type of system installed on your equipment will depend on the operational requirements of the equipment. Some electronic equipments require very close regulation of the temperature of the distilled water, whereas others do not.

TYPE I LIQUID-COOLING SYSTEM

The type I liquid-cooling system is a seawater/distilled-water (SW/DW) heat exchanger with an SW/DW heat exchanger standby. This system is used for electronic system installations that can be operated satisfactorily with seawater temperature as high as 95°F, which should result in a distilled-water supply temperature to the electronics of approximately 104°F. Refer to figure 2-1 as you study this section.

Starting with the distilled-water pumps, distilled water under pressure flows to the temperature-regulating valve. The temperature-regulating valve is installed to partially bypass distilled water around the seawater-to-distilled-water heat exchanger so that a constant water temperature can be supplied to the electronic equipment. As the temperature in the distilled water increases, more water is directed to the heat exchanger and less to the bypass line, thus maintaining the output water temperature constant.

The standby heat exchanger is usually of the same design and is used when the on-line heat exchanger is inoperable or is undergoing maintenance. The size of the heat exchanger is designed to handle the full cooling load of the electronic equipment plus a 20-percent margin. From the heat exchanger, the water then goes through various monitoring devices, which check the water temperature and flow.

The water temperature and flow depend on the requirements of the electronic equipment being cooled. After the water moves through the equipment, it is drawn back to the pump on the suction side; thus, a continuous flow of coolant is maintained in a closed-loop system.

An expansion tank in the distilled-water system compensates for changes in the coolant volume and provides a source of makeup water in the event of a secondary system leak. When the expansion tank is located above the highest point in the secondary system and vented to the atmosphere, it is called a *gravity tank.* If it is below the highest point in the secondary cooling system, it is called a *conpression tank* because it requires an air charge on the tank for proper operation.

The demineralizer is designed to remove dissolved metals, carbon dioxide, and oxygen. In addition, a submicron filter (less than one-millionth of a meter) is installed at the output of the demineralizer to prevent the carry-over of chemicals into the system and to remove existing solids.

TYPE II LIQUID-COOLING SYSTEM

The type II liquid-cooling system is an SW/DW heat exchanger with a chilled-water/distilled-water (CW/DW) heat exchanger standby. This system is used in installations that cannot accept a DW temperature higher than 90°F. Refer to figure 2-2 as you study this section.

The secondary cooling system of the type II liquid-cooling system is similar to that of the type I secondary liquid-cooling system and uses many of the same components—the major difference is in the operation of the CW/DW heat exchanger. The secondary coolant is in series with the SW/DW heat exchanger and automatically supplements the cooling operation when the SW/D Wheat exchanger is unable to lower the temperature of the distilled water to the normal operating temperature.

The CW/DW temperature-regulating valve allows more chilled water to flow into the primary cooling system to the CW/DW heat exchanger. This causes the temperature in the secondary system to go down. Normally, this action occurs only if high seawater temperatures are encountered in tropical waters. The CW/DW heat exchanger is also used in an SW/DW heat exchanger malfunction.

TYPE III LIQUID-COOLING SYSTEM

The type III liquid-cooling system is a CW/DW heat exchanger with a CW/DW heat exchanger standby, and is used in installations where the temperature range is critical. It requires close regulation of the DW coolant to maintain temperatures between established limits. For example, the temperature limits might be between 70°F and 76°F. This system is used where tighter control is required. Refer to figure 2-3 as you study this section.

The type III secondary liquid-cooling system also operates in a similar manner to the type I secondary liquid-cooling system—the major difference is in the way that the temperature of the secondary coolant is regulated. A three-way temperature-regulating valve is not used, but a two-way temperature-regulating valve is used in the primary cooling loop to regulate the temperature of the secondary loop.

The duplicate CW/DW heat exchanger is installed parallel to the first heat exchanger and is used as a standby heat exchanger. If a malfunction occurs that requires the first heat exchanger to be removed from service, the standby exchanger can be put into service by manipulating the isolation valves associated with the two heat exchangers.

LIQUID-COOLING SYSTEM COMPONENTS

The main components of liquid-cooling systems are heat exchangers, expansion tanks, seawater strainers, temperature-regulating valves, flow regulators, flow-monitoring devices, circulating pumps, demineralizes, oxygen analyzers, and coolant-alarm switchboards. In some systems, there are specialized components to monitor cooling water to the electronic equipment.

You should be able to identify and describe the operation of the individual components of a typical liquid-cooling system to help you perform the required system maintenance and trouble isolation. You should never neglect the cooling system, because it will quickly deteriorate to a point where only extreme and costly maintenance will restore it to its proper performance.

HEAT EXCHANGERS

In liquid-cooling heat exchangers, the heat that has been absorbed by distilled water flowing through the electronic components is transferred to the primary cooling system, which contains either seawater or chilled water from an air-conditioning plant. In both cases, the heat exchangers are of the shell and tube type in which the secondary coolant (DW) flows through the shell, while the primary coolant (SW or CW) flows through the tubes.

A single-pass counterflow heat exchanger is more efficient than the double-pass heat exchanger, because there is a more-uniform gradient of temperature difference between the two fluids. The primary coolant (SW/CW) flows through the tubes in the opposite direction to the flow of the secondary coolant (DW). Heat transfer occurs when the seawater flows through the tubes, extracting heat from the distilled water flowing through the shell side of the heat exchanger. The distilled water is then directed by baffles to flow back and forth across the tubes as it progresses along the inside of the shell from inlet to outlet. In figure 2-4, the preferred method of double-tube sheet construction is shown. Single-tube sheet construction is shown in figure 2-5.

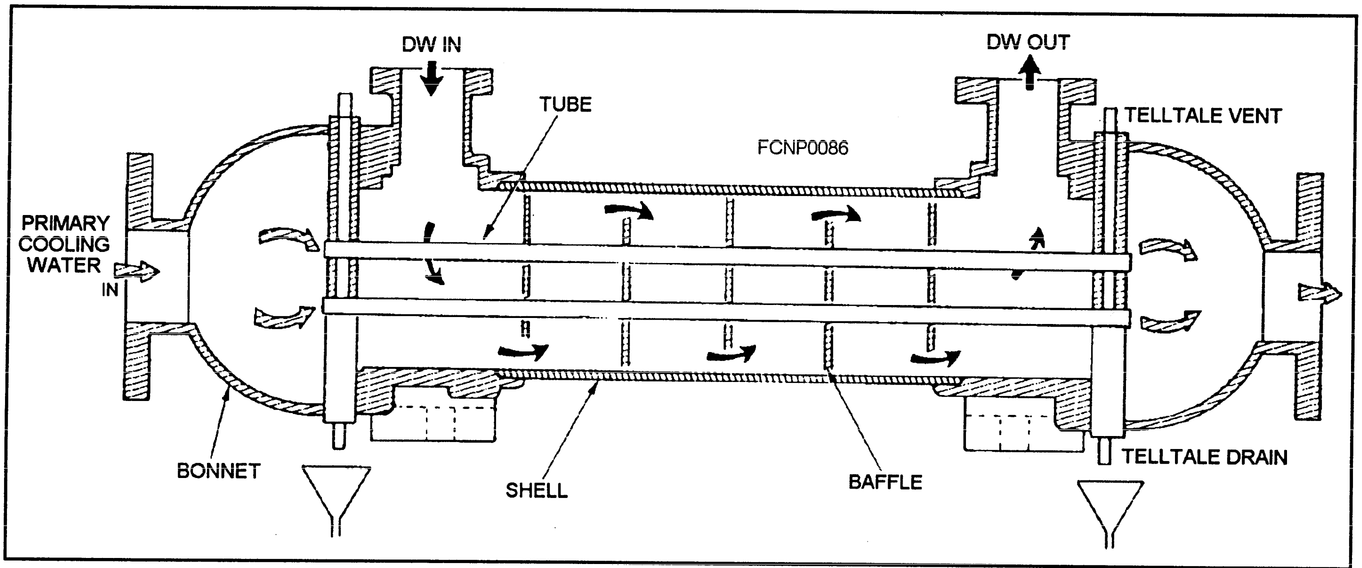

Figure 2-4.—Single-pass SW/DW heat exchanger with double-tube sheets.

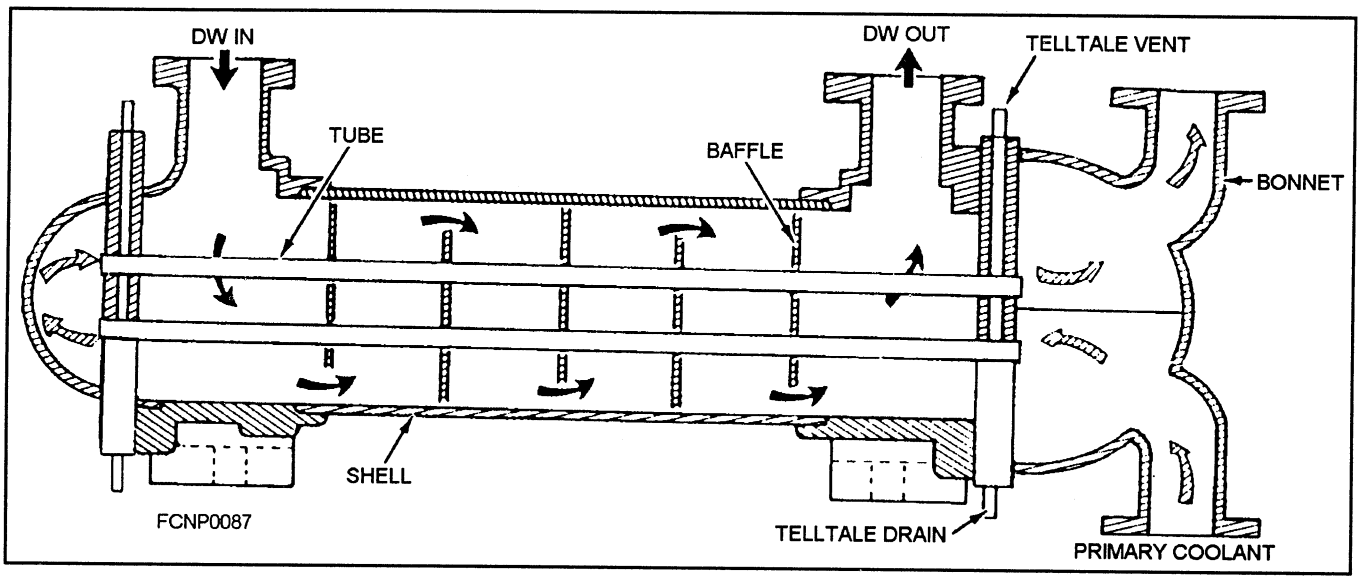

Figure 2-5.—Two-pass SW/DW heat exchanger with single-tube sheets.

Double-tube sheets are used at both ends of a tube bundle. A void space between the sheets prevents contamination of the distilled water and permits the monitoring of water loss due to tube leakage. You should be on the lookout to detect leakage at the "telltale drains," which indicates a failure of a tube joint. The type of water leaking out indicates whether the failure is in the primary or secondary system. The telltale drains should never be plugged or capped off.

A leak in one of the tubes shows up as a loss of water in the secondary side of the liquid-cooling system, because it operates at a higher pressure than the primary side. This is intentional, as it ensures that the distilled water is not contaminated with seawater when a leak develops in a heat exchanger.

A double-pass heat exchanger is generally used when there is limitation on the installation of the heat exchanger. This type of heat exchanger is less efficient than a single-pass exchanger and is subject to internal undetectable leakage across the flow divider in the inlet-outlet water box.

Heat exchangers must periodically be cleaned. The secondary section (distilled water) is cleaned by circulating chemicals through the secondary cooling system to remove any buildup of scale deposits that may accumulate on the surface of the tubes.

The procedure for routine cleaning of the primary section of the heat exchanger is to first secure the sea connections to prevent flooding. In some cases, an inspection port in the water box can be opened to remove any foreign matter lodged inside and against the tubes. If you are unable to get at the ends of the heat exchanger to remove the water boxes, then you must remove the heat exchanger from its location and place it on the deck or on a suitable work surface. Mark each unit removed so that it can be positioned in its proper place during reassembly. With the water boxes removed, an air lance should be passed through each tube and the passages washed out. Where severe fouling exists, a water lance should be pushed through each tube to remove foreign matter attached to the tube walls.

Where extreme fouling exists, special cleaning equipment operated by personnel skilled in its use is required. The ship's engineering officer is normally the best person qualified to determine which procedure to use and whether the job can be performed aboard ship or if it must be transferred to a repair facility. You should take precautions to ensure that tools, such as screwdrivers and wire brushes, are not used in such a way that they may scratch or mar the tube surfaces.

Over a period of time, electrolysis, which results because of dissimilar metals in the cooling system, will slowly dissolve the insides of various components in the primary seawater cooling system. Electrolysis is not a problem in chilled-water systems to the extent that it is in seawater systems. The type of metal used in the fabrication of the heat exchanger tubes is the deciding factor as to the use of zincs. Zincs are disks, rods, bars, or plates made of zinc metal that are installed inside the heat exchanger's water boxes. When they are installed, the electrolytic action is concentrated on the zinc and not on the metal of the heat exchanger tubes. As electrolysis dissolves the zincs instead of the heat exchanger tubes, they should be replaced. (The purity of distilled water inhibits electrolysis in the secondary system.)

In an older cooling system, you should be on the lookout for thin pipes in the seawater side of the cooling system. Check for bad pipes by gently tapping the empty pipes with the ball end of a ball-peen hammer. A bad piece of pipe will make a dull sound and will dimple as it is struck lightly.

The heat exchangers in the distilled-watercooling systems that cool electronic equipment are either liquid-to-air or coolant-jacket type of heat exchangers. The liquid-to-air heat exchangers are mounted inside cabinets containing the heat-producing electronic components.

A cabinet fan circulates the air across the heat exchanger and to the heat source in an airtight circuit. In the coolant-jacket type of heat exchangers, the distilled water is circulated through an integral water jacket in a large heat-producing component, such as a power-amplifier tube, a plate transformer, or the load isolators.

Vent and drain connections are provided to permit venting trapped air and draining water. Temperature gages may be provided in the inlet and outlet piping to check performance of the heat exchanger. Label plates indicate the water-flow direction through each cabinet.

Flow regulators (orifice plates or constant-flow devices) usually provide a constant flow of coolant to the individual component, cabinet, or bay of electronic equipment to be cooled. On critical electronic components that would be damaged without coolant to remove the heat, coolant-flow and temperature switches monitor the coolant.

EXPANSION TANKS

Expansion tanks may be either gravity tanks or pressurized tanks. The expansion tank serves a threefold purpose in a liquid-cooling system. First, it maintains a positive pressure required on the circulating pump inlet for proper operation of the circulating pump. Second, it compensates for changes in the coolant volume because of temperature changes. Third, it vents air from the system and provides a source of makeup coolant to compensate for minor losses due to leakage or losses that occur during the replacement of radar equipment served by the system. Refer to figures 2-6 and 2-7 as you study this section.

When an expansion tank is used as a gravity tank, it is located above the highest point in the distilled-water system. This provides sufficient pressure to the suction side of the circulating pump. It also ensures a flow of water from the tank into the system when makeup water is required.

The tank is provided with a sight glass to check the level of water in the tank. The sight glass should normally show the tank to be from two-thirds to four-fifths full. The glass should be redlined at four-fifths of the tank capacity. A vent pipe is located on the top of the tank to prevent air pressure from building up in the system. A valve and funnel connection with a cap are located on the top of the tank to provide a means for filling the system with distilled water. A low-level alarm switch is usually set at 20 percent of tank capacity.

When the fluid level in the tank lowers to 20 percent of the full level, visual and audible alarms actuate at the alarm switchboard to warn personnel that the system is low on distilled water. If the tank runs out of water, air is drawn into the system, which results in increased corrective maintenance on the system to remove the trapped air or possible pump damage and/or failure of high-power transmitter components.

The pressurized expansion tank is normally located near the circulating pump suction in the return main of the secondary liquid-cooling system. The pressurized tank is airtight and is charged with com-

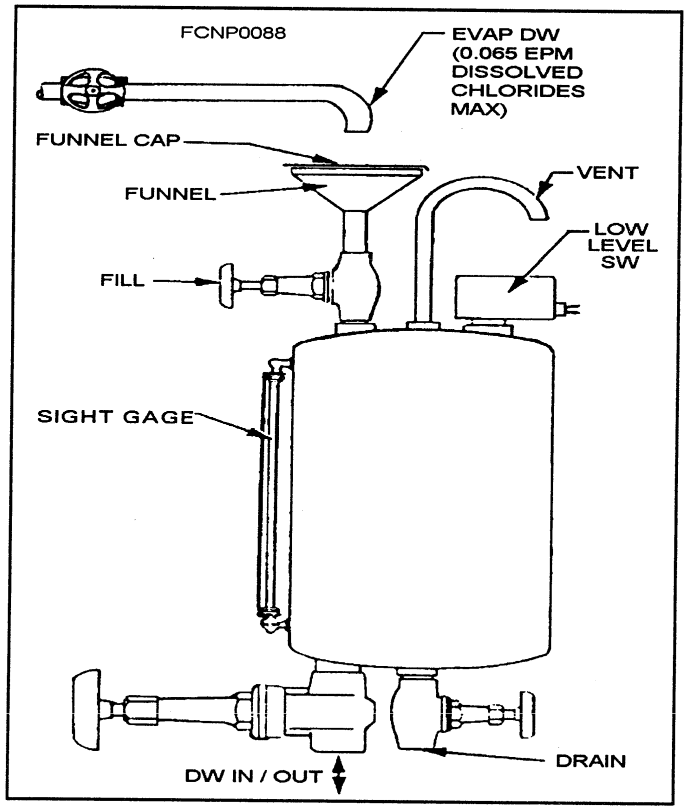

Figure 2-6.—Gravity expansion tank.

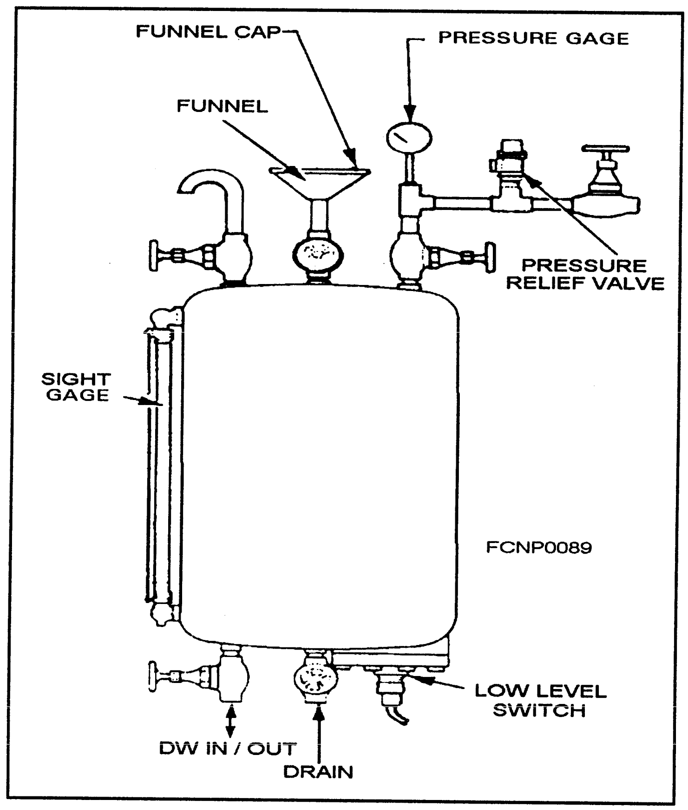

Figure 2-7.—Pressure expansion tank.

pressed air to an appropriate pressure from the ship's low-pressure air system. In some systems, a hose is used to pressurize the tank through a quick-disconnect valve. In other systems, a permanent pipe installation is connected to the expansion tank through a pressure-relief valve and an air shutoff valve.

The ship's low-pressure air system is used to charge the pressure tank, and then it is secured to prevent a possible flood back of coolant into the low-pressure air system. The relief valve protects the tank and the distilled-water system from being overpressurized. The sight glass and the low-level alarm switch function the same as those on the gravity expansion tank.

In both types of expansion tanks, the bottom of the tank is connected by piping to the return main of the secondary cooling system. Changes in coolant volume cause the coolant to flow into or out of the reservoir, as necessary, to maintain a stable return-line pressure.

Makeup water (distilled water) is added to the expansion tank through the funnel on the top of the tank. A funnel cap is provided for the funnel to prevent dirt from entering the system. When you fill the pressurized expansion tank, you must first isolate the tank from the cooling system and the air supply before you vent the air pressure off through the vent pipe at the top of the tank. The makeup water can be obtained directly from the ship's evaporators and preferably when the ship is making boiler-feed water, because the water is double distilled. At **no** time should potable (drinking) water or treated boiler-feed water be used in any electronic cooling systems.

After the water is drawn from the ship's evaporators, it should be transported only in a clean, capped container. You should take a sample of the water from the container and have it tested for chloride by the ship's water test facility before any of the water is used in the cooling system. The maximum permissible level of chloride is 0.065 ppm (equivalent parts per million). The supply system provides an alternate source of makeup water.

The expansion tank sight glass is your best indication of a coolant leak in the secondary cooling system. When the system uses excessive makeup water, you should inspect the whole secondary system, including the telltale drains on the heat exchanger, to locate the source of the leak. A small drip can amount to several gallons of water a day. On the pressurized expansion tank, a very small air leak (indicated by a pressure drop on a tank gage) can be located by brushing on a leak detector (a thick, clear, soapy liquid, such as concentrated liquid dishwashing soap) over the suspected area of the leak. The escaping air causes bubbles to form in the leak detector.

SEAWATER STRAINERS

Strainers are used in the seawater cooling system to remove debris and sea life, which could clog the pressure and flow-control device (orifice) and/or the tubes of the heat exchanger. The two types of in-line seawater strainers most commonly used in weapons cooling systems are the simplex (single) and duplex (double) basket strainers.

The simplex basket strainer, shown in figure 2-8, has a Y-pattern body. (Some simplex strainers have a small drain on the cover to allow you to drain the water off before removing the cover.) The basket is removed periodically for cleaning and inspecting for deterioration. This type of strainer requires that the seawater be secured before you clean the basket.

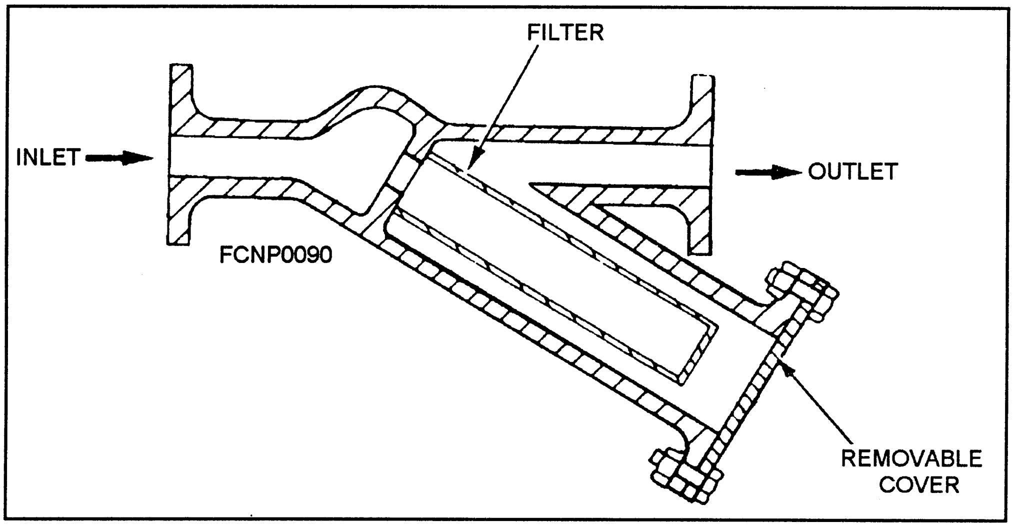

Figure 2-8.—Seawater simplex strainer.

The duplex strainer, shown in figure 2-9, consists of two removable baskets located in parallel at the seawater inlet. Seawater flows into the top of one basket and out through the perforated sides to the outlet. This arrangement allows maintenance to be performed on one basket while the system is in operation.

A selector valve is arranged so that, with the handle in one position, seawater flows through one of the baskets, leaving the other basket accessible for removal and cleaning. When the valve handle is switched to the alternate position, the flow is shifted over to the other basket.

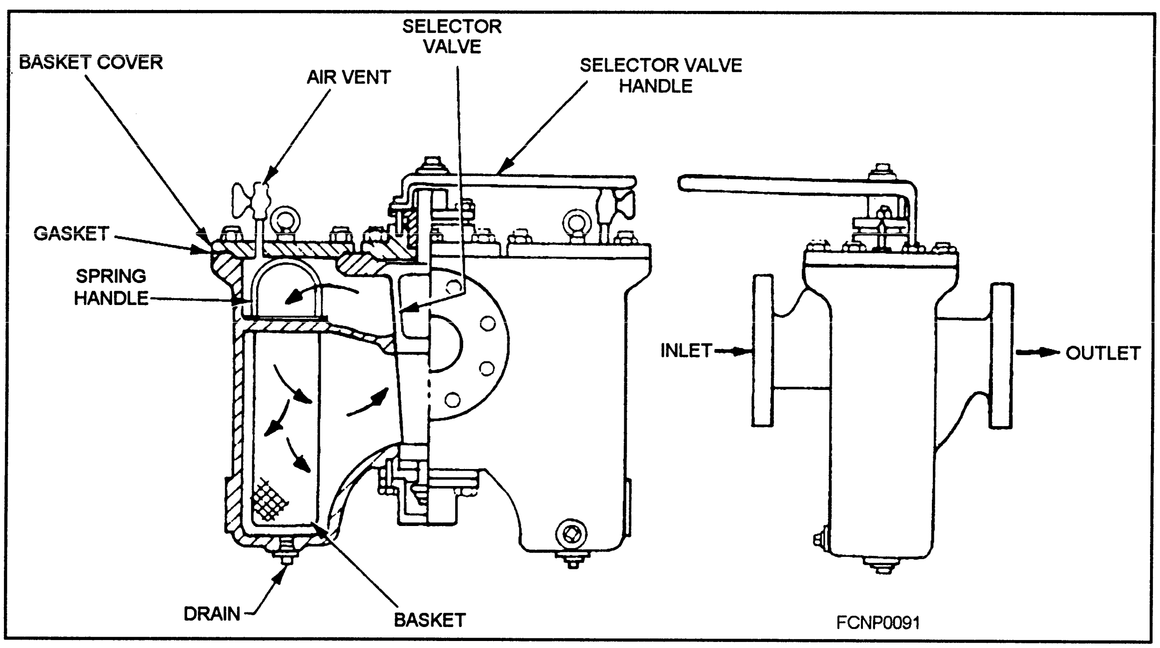

Figure 2-9.—Seawater duplex strainer.

The duplex pressure gage monitors the differential pressure between the inlet and outlet ports of the duplex strainer. The duplex gage provides a visual indication of a clogged strainer basket. To correctly use the gage, you should mark it when the basket is clean. When the basket is clogged, the pressure reading is usually 5 to 10 psi above the clean-basket reading. If the pressure drop is less than the clean-basket reading, you should check for a damaged or missing basket.

The basket handle (spring handle) acts as a spring-load to seat and hold the basket in the housing. A damaged spring handle will permit debris to bypass the strainer basket and clog the heat exchanger tubes. In some cases, the basket may spin inside the duplex strainer and physically wear away the basket seat and/ or the side of the duplex strainer. The duplex strainer would then have to be removed for extensive repairs, possibly off the ship. New or replacement baskets should always be checked for proper spring-handle pressure against the top of the basket cover.

You should use only the correct gasket material for the basket covers, as specified in the Coordinated Shipboard Allowance List (COSAL). Inferior material can stretch and can be forced out from under the cover, permitting seawater to spray out and possibly flood the space.

TEMPERATURE-REGULATING VALVES

The temperature-regulating valves regulate the amount of cooling water flowing through or bypassing a heat exchanger to maintain a desired temperature of distilled water going to the electronic equipment. Temperature regulating is usually provided by a three-way or two-way temperature-regulating valve or a combination of both valves. The three-way valve is used where seawater is the primary cooling medium in the heat exchanger, whereas the two-way valve is used where chilled water is the primary cooling medium.

Three-Way Temperature-Regulating Valves

Three-way temperature-regulating valves are installed in liquid-cooling systems so that the incoming distilled water to the valve can be directed to the heat exchanger or caused to bypass the heat exchanger. More accurately, the distilled water is proportioned between these two paths.

The valve senses the temperature of the distilled water downstream of the junction between the heat exchanger outlet and the bypass and then proportions the two flows to obtain the desired temperature. The operating range of the three-way temperature-regulating valve is within ±5° of the setting on the valve.

The bulb contains a volatile liquid that vaporizes and expands when heated. The pressure generated in the bulb is a function of the temperature around it and is transmitted through the capillary tubing to the flexible bellows, which are loaded by the spring. Both the bellows and the spring rest on the end of the valve stem. Expansion or contraction of the bellows causes movement of the stem and the piston in the valve body. Movement of the bellows is opposed by the spring, which can adjust the operating temperature by the spring-tension adjustment wheel.

A drop in the temperature at the thermostatic bulb reduces the pressure in the thermostatic assembly, causing it to exert less force and resulting in an upward movement of the stem because of the force of the spring. As the stem is connected to the piston, the piston also moves upward, enabling more liquid to pass from the bottom inlet through the right outlet (bypass) side and, at the same time, restricting flow through the left outlet (heat exchanger) side. A rise in temperature at the thermostatic bulb results in a reversed effect.

Figure 2-10 shows a three-way temperature-regulating valve.

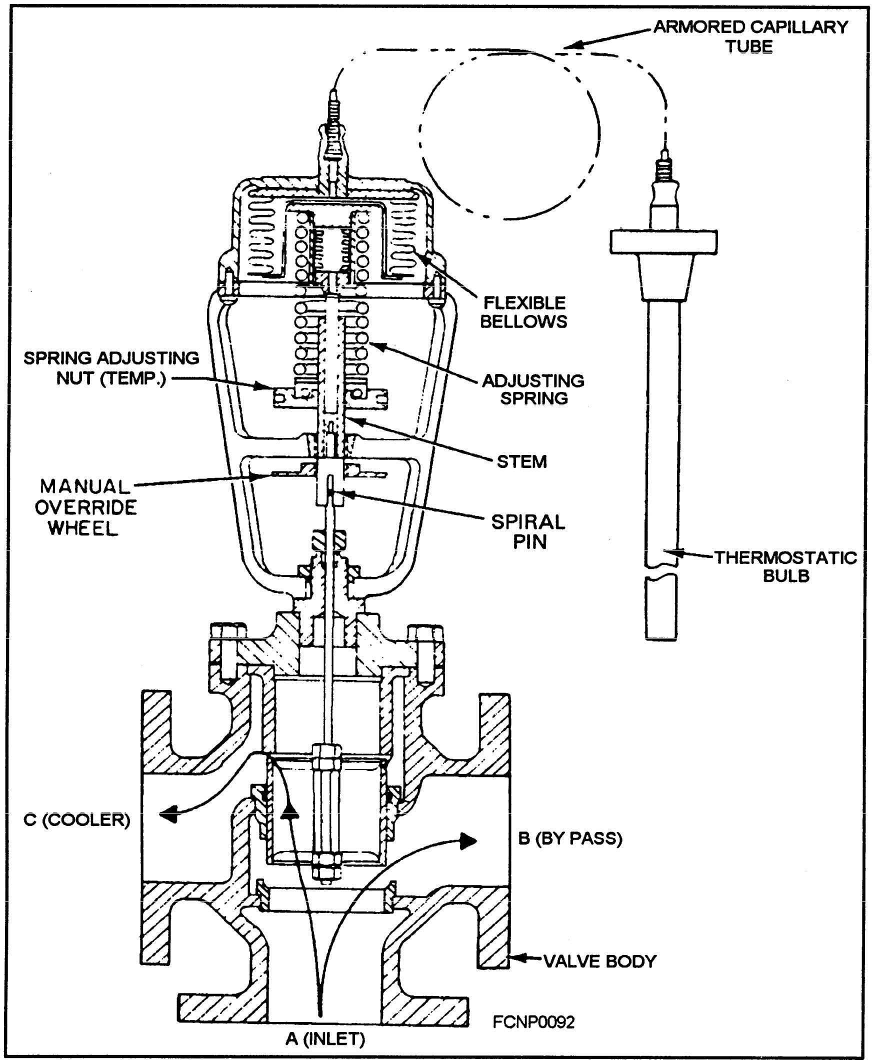

Figure 2-10.—Three-way temperature-regulating valve.

Two-Way Temperature-Regulating Valves

Two-way temperature-regulating valves in liquid-cooling systems are normally installed in the chilled-water supply to the heat exchanger with the thermostatic sensing bulb installed in the distilled-water outlet from the heat exchanger. The basic operation of the two-way temperature-regulating valve is the same as that of the three-way temperature-regulating valve. If the temperature of the distilled water is above the desired temperature, the two-way valve gradually opens to increase the flow of chilled water through the heat exchanger, which keeps the distilled-water temperature at the desired point.

Both the three-way and two-way temperature-regulating valves have a manual override feature to provide uninterrupted service, if the thermostatic assembly should fail due to damage to the capillary tubing or any other component of the thermostatic assembly. With the use of the manual override wheel, you can set the valve plunger/piston in the required position to operate the liquid-cooling system by turning the manual override wheel down (from right to left) until it touches the spiral pin in the valve stem. Beyond this point, the valve plunger/piston is forced down, allowing the flow of cooling medium through the valve. With the use of the installed thermometers, you can decide if more or less cooling is needed by turning the manual override wheel up or down. The use of the manual override inhibits the thermostatic assembly and should be used only when the thermostatic assembly is inoperable. Corrective maintenance of the regulating valve consists of inspecting the valve for leaks and for freedom of stem movement, adjusting the set point at which the valve regulates, renewing the thermostatic assembly, and cleaning and restoring valve parts. Any time that you remove a valve, you should center punch a dot code on each piece to ensure that the valve and the piping are installed in the original configuration.

Individual maintenance manuals for temperature-regulating valves should be closely followed. For example, if you remove the top of the thermostatic assembly without chilling the temperature probe, the bellows will expand and rupture, making the unit worthless. To verify that the thermostatic assembly has failed, close the valves upstream and downstream of the thermostatic bulb, drain the unit below the location of the bulb, and remove the bulb from its well. Place the bulb in a suitable vessel and observe the valve stroke while the bulb is alternately heated with hot water and cooled with cold water. If the valve thermostatic assembly does not respond, it has lost its thermostatic charge, and anew unit must be installed.

Figure 2-11 shows a two-way temperature-regulating valve.

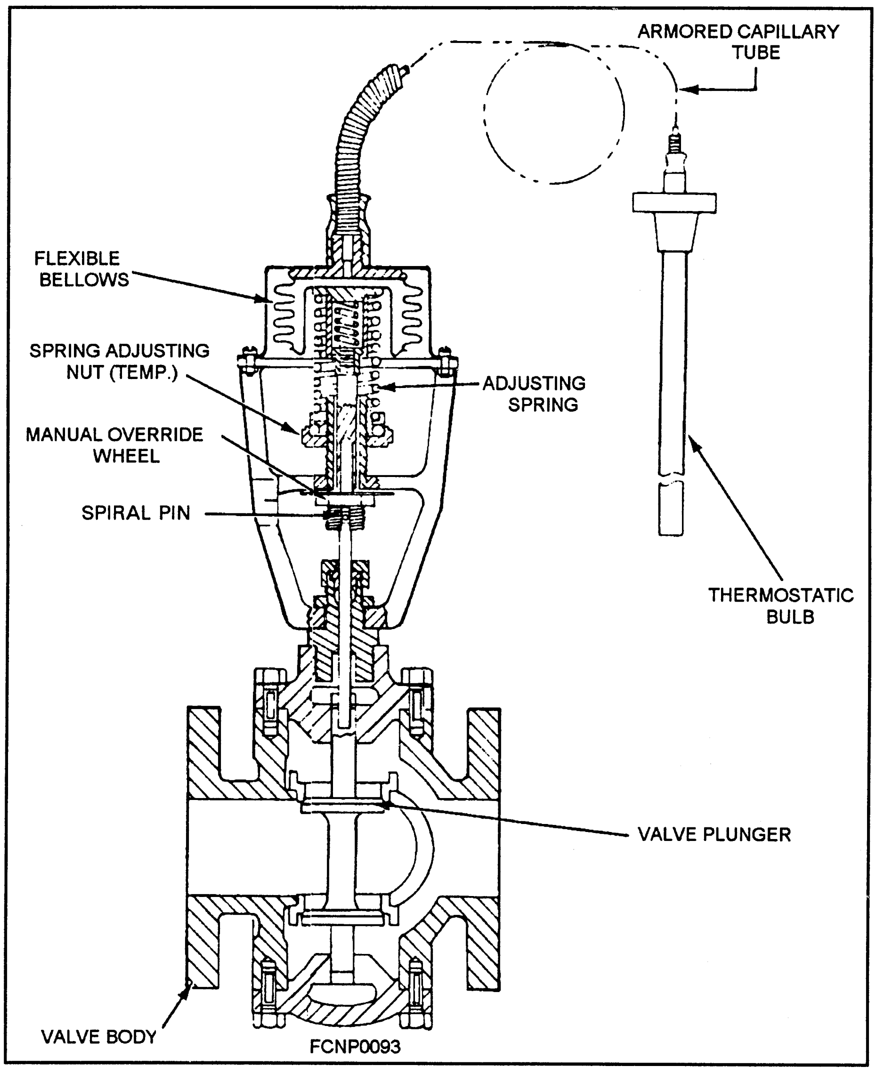

Figure 2-11.—Two-way temperature-regulating valve.

FLOW REGULATORS

Many different types and sizes of flow-regulating devices are used in both the primary and secondary cooling systems to reduce the pressure or flow of coolant through a cooling system. Figure 2-12 shows a constant-flow regulator.

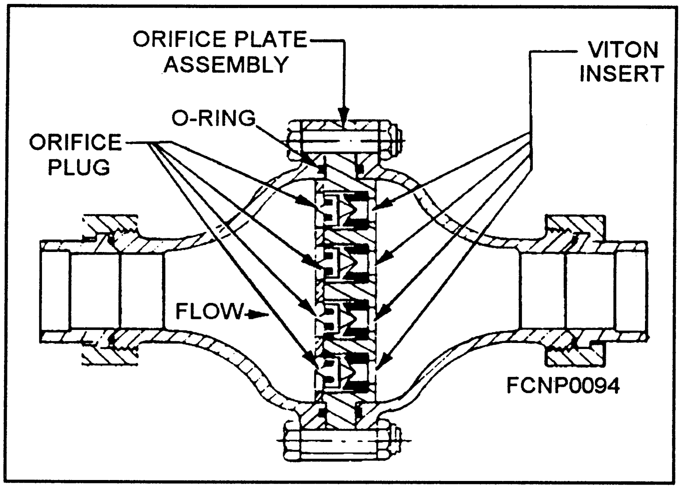

Figure 2-12.—Constant-flow regulator.

The orifice plate is found primarily in the seawater cooling system. It is the simplest design of a flow-regulating device and consists of a steel plate with a hole in it. With constant known seawater pressure and with a given hole size, the volume of water through the device can be determined. The use of an orifice plate is limited to where the input water pressure is essentially constant, such as the ship's fire main.

The orifice plate is normally installed between two pieces of flanged pipes upstream from the heat exchanger. This reduces the ship's fire-main pressure below the pressure in the secondary cooling system. If one of the heat exchanger tubes fails, the seawater pressure will be lower than the distilled-water pressure; therefore, it will not contaminate the secondary cooling system, as the secondary cooling system will force distilled water into the primary cooling system.

A ruptured heat exchanger tube or a bad single-tube sheet in a heat exchanger will give no visual indication of water loss except for the indication on the expansion tank sight glass.

To stabilize the flow of seawater and to prevent jet erosion of the heat exchanger and associated piping, the orifice plate should be installed with at least 15 pipe diameters of straight pipe upstream from the heat exchanger. When there is a drop in the heat exchanger primary input pressure and the seawater supply pressure has not changed, you should first check the duplex strainer differential pressure gage to ensure that the duplex strainer is clean. Then you should inspect the orifice plate for deposits or particles that could restrict the seawater flow. Also, you should inspect the orifice plate for erosion damage of the hole diameter. (Replace the orifice plate when there is an increased flow of seawater to the point that it could damage the heat exchanger.)

Never use the seawater valves to throttle (partially close) the flow of seawater in the primary cooling system, because the seawater will erode the internal parts of the valve. Such misuse would damage the valve, requiring extensive repair or replacement because it would no longer close properly.

When used with the chilled-water system, the constant-flow regulator (variable orifice) is installed downstream from the heat exchanger. This restricts the flow from the heat exchanger and keeps the heat exchanger fully submerged for greater efficiency (heat transfer). This flow regulator is not used in the seawater system because the internal parts would easily become fouled with marine growth and deposits. The operation is dependent on the movement of the orifice plugs (neoprene) to regulate the flow of water.

The equipment-flow regulator is used primarily with electronic equipment to regulate the flow of distilled water through the individual cabinets and components. It maintains a constant flow of distilled water with limited changes in the input pressure. At the minimum water flow, the total amount of water is passed through the device. As the flow of water increases to the flow regulator's maximum limit, the water flow is restricted by the movement of the insert, which causes the hole size to decrease, thereby regulating the flow of water. The amount of water that the flow regulator will pass is usually stamped on the side of the regulator. This is because the external dimensions are usually the same for differently rated regulators.

Normally used with a pressure-regulating valve, the nominal flow rate of the equipment-flow regulator, shown in figure 2-13, can be from 1/2 to more than 12 gallons per minute. However, this type of regulator can deteriorate over time, with the insert becoming distorted and causing a reduction in water flow. With a drill index set, you can use the back of a drill bit to measure the hole size and compare it to a known good constant-flow regulator or to the equipment manual. Do not drill out the insert to restore it to the proper size, because it will become distorted, thus preventing the insert from regulating the distilled-water flow.

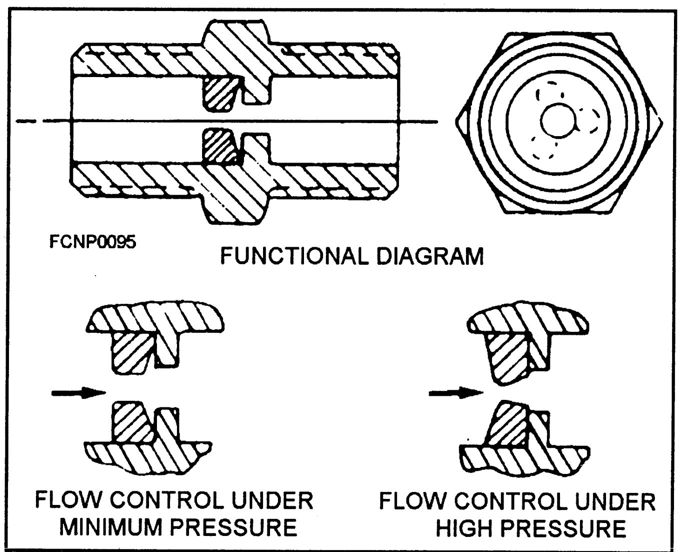

Figure 2-13.—Equipment-flow regulator.

The pressure-regulating valve is used to regulate a major section of the cooling system, whereas the flow regulator is normally used to regulate an individual feeder line to an individual component or cabinet. The pressure-regulating valve usually has a pressure-relief valve downstream from it to protect the equipment from becoming overpressurized. If a failure occurs in the pressure-regulating valve, the pressure-relief valve will keep the water pressure at a safe level to prevent equipment damage.

In a typical pressure-regulating valve, when a drop in downstream (outlet) pressure occurs, the pressure in the diaphragm chamber is lowered concurrently. The downstream side of the valve is connected to the diaphragm chamber through a narrow opening along the periphery of the piston.

The spring is allowed to force the diaphragm downward, releasing the tension on the rocker arm, and the inlet pressure opens the valve. The outlet pressure increases to the preset level, and the static control chamber pressure balances the valve spring to maintain a regulated downstream pressure to the served equipment.

You should take certain precautions with this type of valve. For example, ensure that the locknut is loose before you adjust the adjusting screw; otherwise, you could strip the threads of the brass spring chamber. If water starts leaking out of the vent, have the valve serviced for a leaking diaphragm before it ruptures. Never plug or paint over the vent to inhibit its operation.

If you remove a flow regulator or a pressure regulator, make certain that you reinstall it correctly, as it can be installed backwards. Look for an arrow for the direction of the flow or the inlet and outlet stamped on the body of the device. Pipe-joint sealant should be used only on the male pipe threads and not closer than one thread to the open end to seal the device. Figure 2-14 shows a pressure regulator.

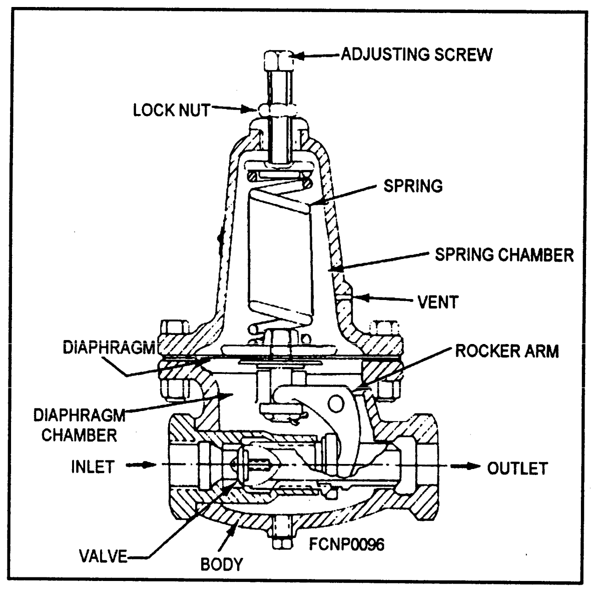

Figure 2-14.—Pressure regulator.

FLOW-MONITORING DEVICES

Most systems incorporate one or more types of devices to monitor the flow of distilled water through the system to ensure that the electronic equipment is supplied with an adequate flow of distilled water. A low-flow switch is normally found in the secondary cooling system to monitor the overall coolant flow. It is electrically connected to a common alarm circuit to warn personnel when the system flow rate drops below a specified minimum value. A typical cooling system low-flow switch is shown in figure 2-15.

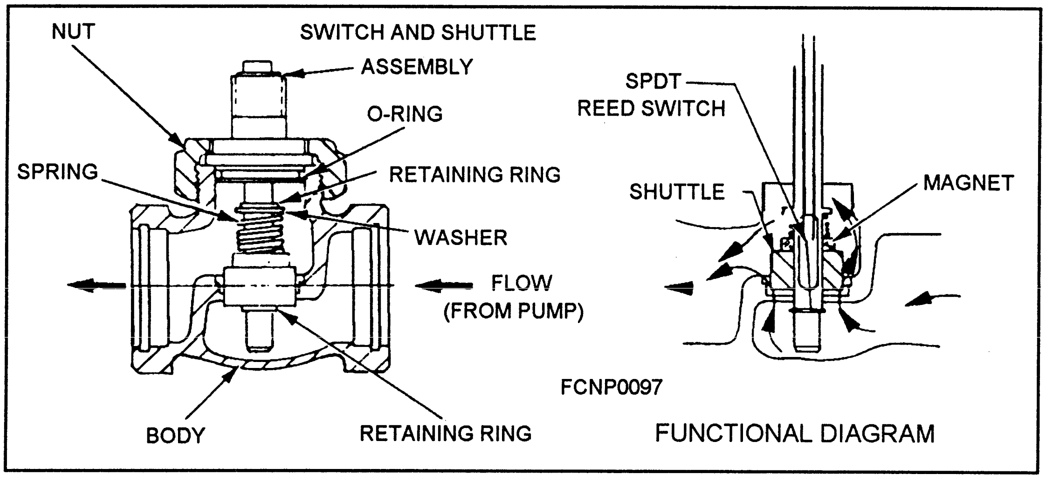

Figure 2-15.—Cooling system low-flow switch.

The main operating parts of the cooling system low-flow switch consist of a hermetically sealed reed switch and a permanent magnet attached to an internal shuttle. With the proper flow of coolant, the shuttle moves the magnet up and away from the reed switch, which keeps the reed switch contacts open. When the coolant flow drops below the minimum for a flow switch, the shuttle is forced down by the spring to a balanced condition against the flow of the distilled water. The magnetic field is now close enough to cause the reed switch to close and to activate the low-flow alarm.

A small flow switch is used in electronic equipment to monitor the flow to individual components. The flow of water through the orifice causes a pressure drop across it. This pressure drop causes the diaphragm to move against the spring. When the differential pressure (pressure drop) is sufficient, the microswitch activates to indicate that the switch has the proper flow through it. You should be sure that the flow switch is defective before overhauling or replacing it, as the problem could be a partially closed supply/return valve, an obstruction in the coolant line, an insufficient coolant pressure, or many other things. By using the coolant system pressure gages and/or the installation of a permanent or a temporary in-line flowmeter, you should be able to correctly isolate the problem.

In the secondary cooling system, a full-flow system flowmeter is provided to enable you to monitor the total system flow rate for troubleshooting purposes. Three types of system flowmeters are installed aboard ships; all of which monitor the coolant-flow rate. They are the venturi flowmeter, the orifice flowmeter, and the rotameter. Most systems incorporate one secondary coolant flowmeter and one or more smaller flowmeters to ensure that the electronic equipment is being supplied with an adequate flow of coolant.

A typical equipment-flow switch is shown in figure 2-16.

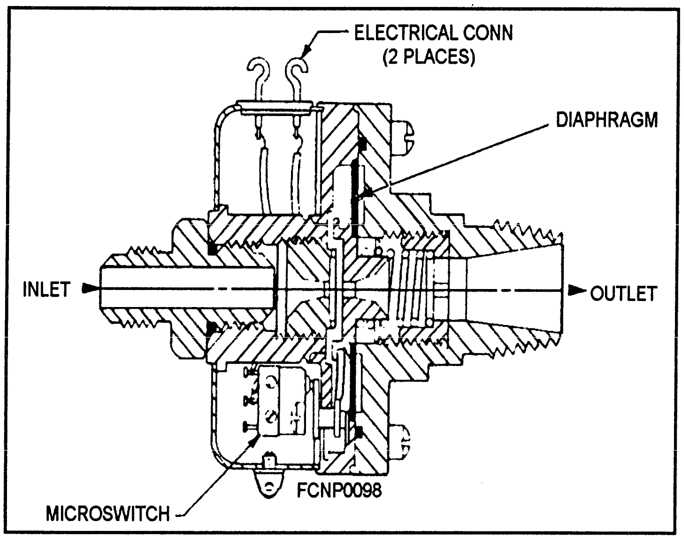

Figure 2-16.—Equipment-flow switch.

● **Venturi Flowmeter:** As the coolant approaches the contracted portion (throat) of the venturi flowmeter, the velocity of the coolant must increase as it flows through the contracted zone (throat). The angle of approach is such that no turbulence is introduced into the stream. A pressure tap is located at the side wall in the pipe ahead of the meter, and another one is located at the throat. The increase in velocity of the coolant water through the throat results in a lower pressure at the throat. The flow rate is proportional to the difference in pressure between the two taps. The gradual tapering of the meter walls back to pipe size downstream of the throat allows the coolant water to slow down with a minimum of lost energy. This allows a recovery of nearly 99 percent of the pressure on the approach side. To monitor the amount of flow through the venturi flowmeter, a differential pressure gage is used to monitor the pressure difference between the two pressure taps. A calibration chart is usually supplied with the flowmeter to convert the different pressure to gallons per minute (gpm), or the face of the meter may indicate readings in gpm. Figure 2-17 shows a venturi flowmeter.

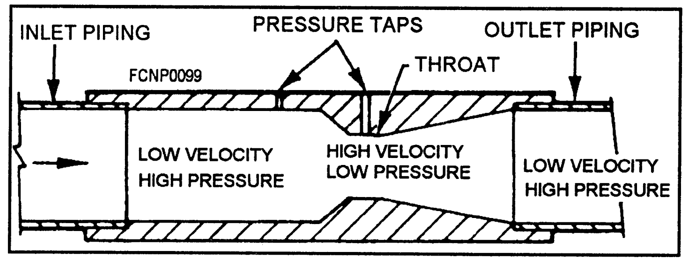

Figure 2-17.—Venturi flowmeter.

● Orifice Flowmeter: The orifice flowmeter works in the same manner as the venturi flowmeter, but its construction is much simpler and less expensive to manufacture. In place of the tapered throat, the orifice flowmeter uses a flat plate with a hole in it, which causes a considerable loss of pressure downstream. The efficiency of this type of flowrneter can be as low as 65 percent.

● **Rotameter:** The rotameter, shown in figure 2-18, is a variable area orifice meter that maintains a constant differential pressure with varying flow. The rotameter has a float positioned inside a tapered, tempered glass tube by the action of the distilled water flowing up through the tube. The flow restriction is the space between the float and the tube wall; this area increases as the float rises. The differential pressure is fixed, depending on the weight of the float and the buoyant forces resulting from the combination of float material and the distilled water's specific gravity. The tapered tube of the rotameter is usually glass, with calibration marks reading directly in gpm. The major advantage of a rotameter over a venturi meter is the visibility of the coolant, as it allows quick determination of excessive entrained air in the coolant.

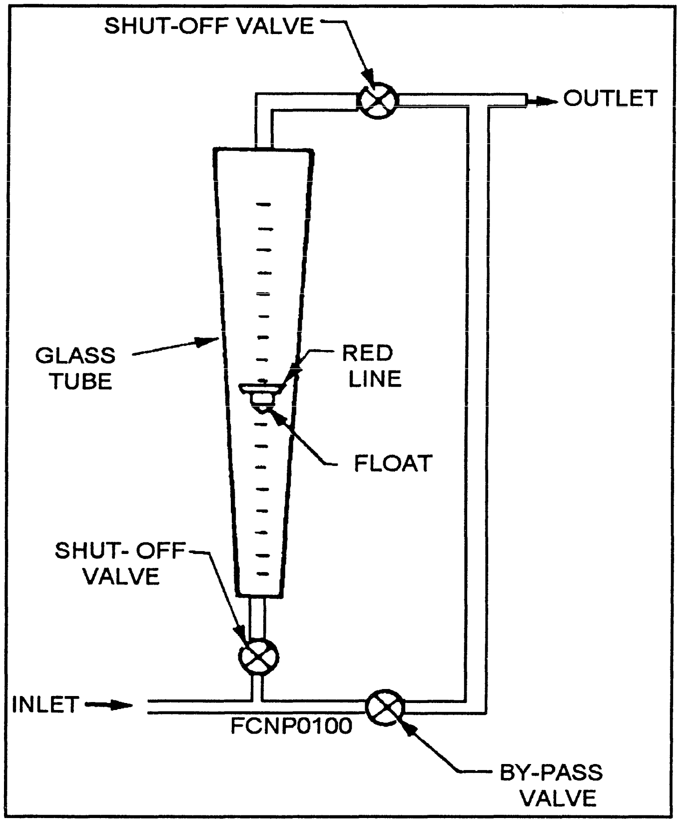

Figure 2-18.—Rotameter.

CIRCULATING PUMPS

Each cooling system has two secondary distilled-water circulating pumps. These pumps are identical in construction and capacity. One pump is designated for service, and the other is held in standby in case the designated pump fails. If the pump designated for operation fails, then the standby pump is used in its place. The pumps should be operated alternately (every other week) to prevent deterioration of the shaft seals, to equalize wear, and to permit Planned Maintenance System (PMS) actions to be performed regularly.

The two circulating pumps used in liquid-cooling systems are single-stage centrifugal pumps, closely coupled to a constant-speed electrical motor (the pump is built onto the motor). (Some older systems use a separate pump and motor joined by a flexible coupling.)

The centrifugal pump has two major elements—the impeller rotating on the extension of the electric motor shaft, and the casing (the impeller chamber). The impeller imparts the initial velocity to the coolant and collects the high-velocity coolant from the impeller and guides it to the pump outlet. A mechanical shaft seal is used to eliminate external leakage; this seal is lubricated and cooled by water ducted from a high-pressure zone of the pump. A vent valve is on the top of the pump casing to remove air and to ensure that the pump is primed with coolant.

Located at the outlet of each pump is a check valve to prevent coolant from the outlet side of the operating pump from circulating to the return side of the coolant system through the standby pump. Hand-operated valves at the pumps are used to isolate the pumps so that they can be removed for maintenance.

Each secondary circulating pump is rated in a gpm output at a specified head pressure in pounds per-square-inch-gage (psig) pressure, or in feet of water. The rating is usually at the pump's maximum efficiency point and varies depending on the pump design. On all pumps, as the output pressure increases, the output flow decreases, and vice versa. This relationship is almost linear, but varies with different pump designs. However, this condition means that if a restriction is placed in the pump output lines, the pressure will increase and the flow will decrease. The restriction could be a partially closed hand valve, a dirty filter, a damaged or crimped piping or hose, etc.

The pump performance indicators are the suction and discharge pressure gages and the system flowmeter. If you start a pump and the pressure fails to build up, you should exhaust air through the vent cock on the top of the pump casing. You should ensure that the suction valve is fully opened and that there is pressure on the pump suction pressure gage. If the flow doesn't develop, you should check for clogging and wear. *Never operate a pump without coolant flow.*

Some pumps have a small recirculating line that enables the pump to recirculate coolant from the discharge side of the pump to the suction side to provide for a flow of coolant through the pump if an inlet or outlet valve to the pump is closed with the pump running. Whatever the case, keep in mind that the operation of a pump without the normal flow of coolant through it will result in overheating and seizure of the pump. Included in the corrective maintenance of the circulating pump are repairing any leaks, replacing the mechanical seal, and cleaning the internal parts.

This type of maintenance is normally performed by the ship's engineering department; you should provide assistance if it is needed. Figure 2-19 shows a distilled-water circulating pump.

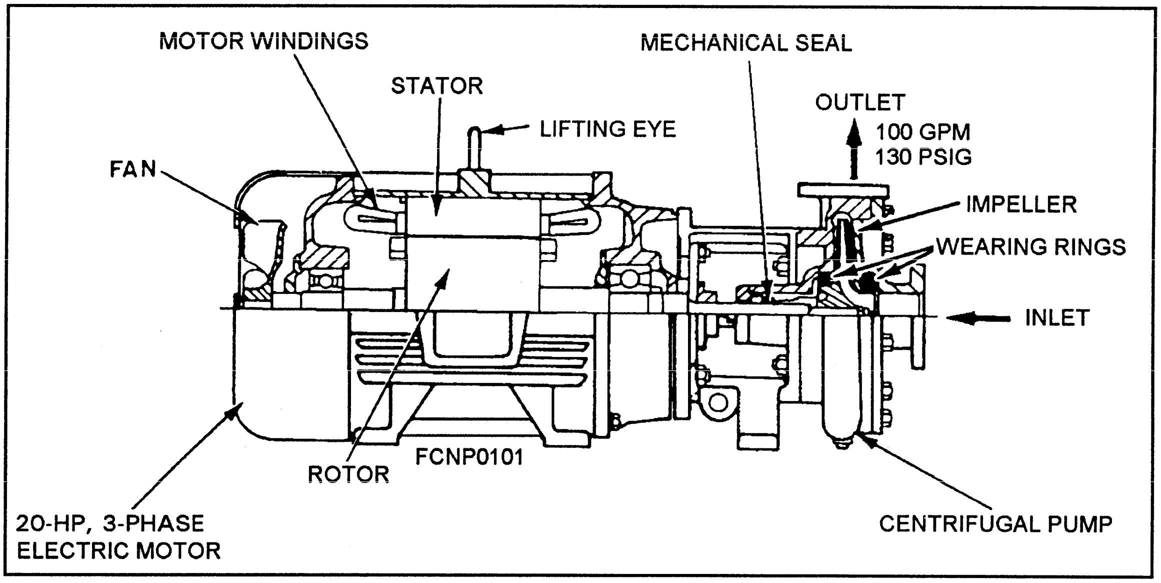

Figure 2-19.—Distilled-water circulating pump.

DEMINERALIZERS

Demineralizes are used to maintain the secondary cooling system's water purity in an ultrapure state. By maintaining the coolant at a high degree of purity, corrosion and scale formation is minimized on the radar unit.

Corrosion or scale on high-heat-density components, such as waveguide dummy loads and klystrons, results in the formation of a thermal barrier. The thermal barrier reduces the effectiveness of heat transfer at normal operating temperatures, which, in turn, leads to premature failure of the components.

The demineralizer is connected between the secondary cooling system supply and return lines to circulate water through it. The demineralizer is sized so that 5 percent of the cooling system volume passes through the demineralizer every hour. The coolant is purified by organic compound adsorption (if required), oxygen removal, ion exchange processes, and submicron filtration.

Figure 2-20 shows a typical three-cartridge demineralizer. Some demineralizers use only two cartridges, with one of the cartridges being a combination cartridge that provides organic compound adsorption, if it is required.

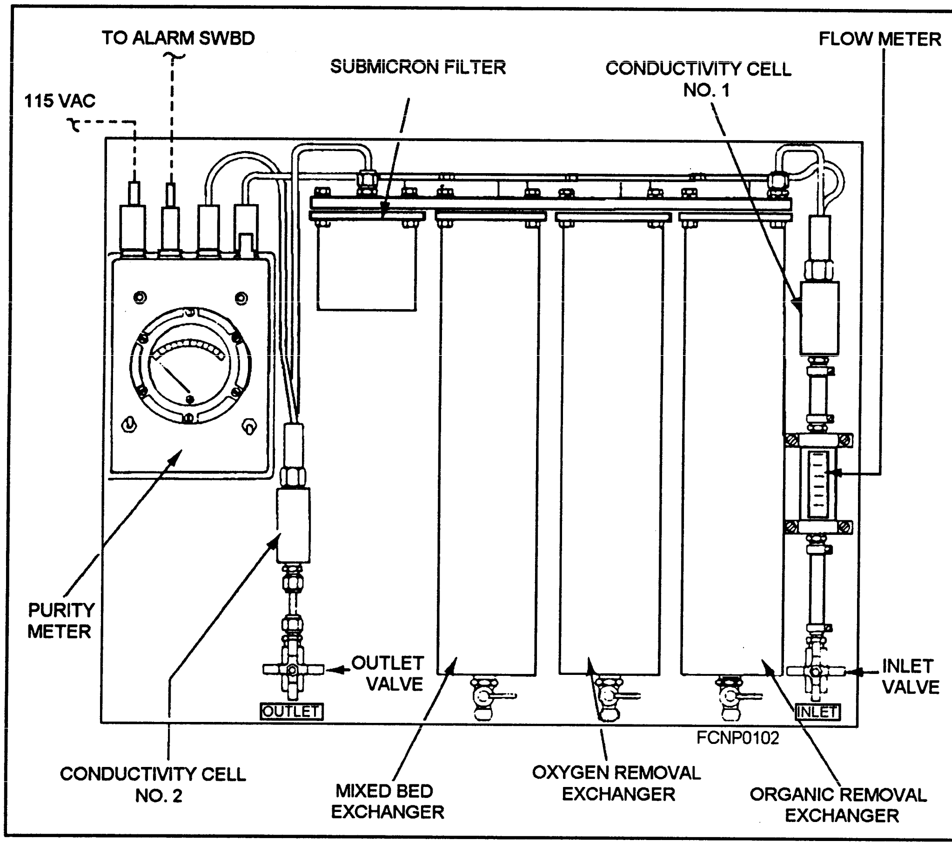

Figure 2-20.—Demineralizer.

The inlet supply valve to the demineralizer must be adjusted on system start-up and periodically thereafter to maintain the correct flow rate through the flowmeter. Too high a flow rate can damage the cartridges. If the flow rate cannot be increased to the proper rate with the inlet supply valve fully open, you should check to ensure that the outlet valve is filly open.

The submicron filter is used to remove small particles that have a size greater than 0.5 micron from the coolant flow. If the filter becomes clogged, it also reduces the flow of coolant, which necessitates a change of the filter cartridge or filter sheet (the membrane). To change the filter, you must properly position the demineralizer valves. If the filter cartridge or the membrane continually becomes clogged (about 1/2 hour or less after replacement), the usual cause in the distilled-water system is the presence of bacteriological impurities. Bacteriological impurities introduced into the secondary liquid-cooling system using distilled water may exist in the demineralizer cartridges and/or the whole secondary cooling system. If the impurities are in the whole secondary cooling system, the growth rate in a warmwater environment could be of a magnitude that exceeds the capability of the demineralizer. In that case, you must determine the source and magnitude of contamination. However, bacteriological contamination in a secondary cooling system that uses distilled water and ethylene glycol is highly improbable.

Improper handling or storage of the cartridges could cause them to be a source of contamination. Therefore, you should always store the cartridges in a cool, dry area, as exposure to heat hastens the growth of any biological contaminates that may have entered the cartridges. The three types of cartridges are organic removal, oxygen removal, and mixed bed.

- **Organic Removal Cartridge:** The organic removal cartridge, which contains granulated activated charcoal (carbon) to remove large organic molecules and chlorine by adsorption, is always installed in the first exchanger (if required) to prevent organic molecules from fouling the remaining cartridges.

Oxygen Removal Cartridge: The oxygen removal cartridge is composed of anion (negative charge) resins that remove oxygen from the water by ion exchange of sulfite ions to sulfate ions. By conducting a standard oxygen test (if the cooling system has an oxygen analyzer installed), you can test the quality of the outlet water from the demineralizer for oxygen content so that you will know when to replace an oxygen cartridge. When the oxygen cartridge is near exhaustion, it will have a urine odor, which is given off by the sulfate.

Mixed-Bed Cartridge: The mixed-bed cartridge is filled with cation (positive charge) and anion (negative charge) resins, which remove solids, dissolved metals, and carbon dioxide. The charged resins exchange ions with the contaminates, thereby removing them and leaving pure deionized coolant. Replace the mixed-bed cartridge when the purity meter indicates a low outlet purity.

Two conductivity cells monitor the coolant through the demineralizer. The first cell measures the purity of the coolant as it enters the demineralizer. The second cell measures the purity of the coolant as it leaves the demineralizer A conductivity cell consists of two electrodes immersed in the coolant flow path. The electrodes measure the conductivity of the coolant, which varies with the amount of ionized salts dissolved in it. If the impurity content increases in the coolant, the purity meter indicates higher conductance.

On some purity meters, the purity of the coolant is displayed as resistivity. In this typeof meter, an increase in the impurity of the coolant causes the meter to indicate a low resistivity. Conductance is the reciprocal of resistance, and is measured in siemens. Figure 2-21 shows a purity meter.

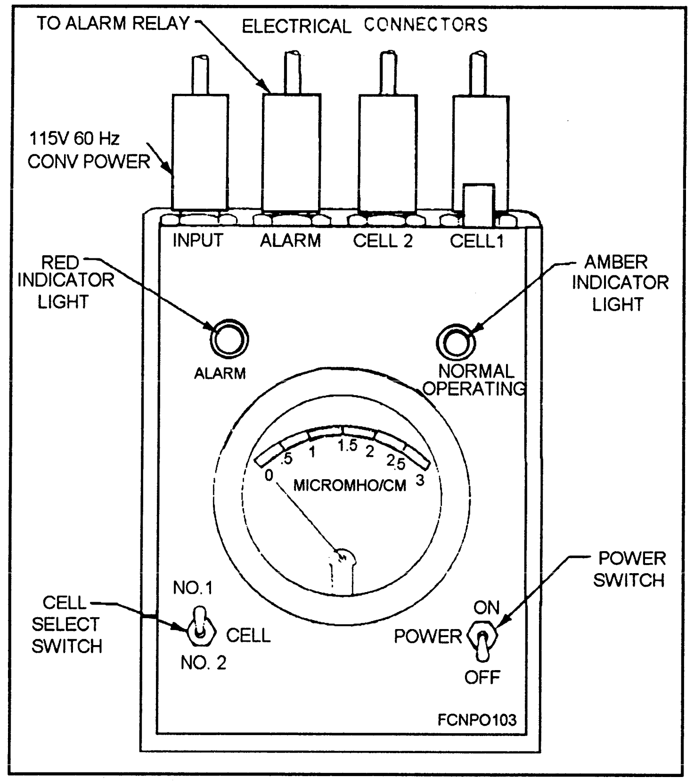

Figure 2-21.—Purity meter.

Resistivity is measured in megohms/cm. You can convert from conductivity to resistivity by taking the reciprocal of conductivity. Similarly, the reciprocal of resistivity is equal to the conductivity. A comparison of both ways of measuring the purity of the coolant is shown in table 2-1.

Table 2-1.—Distilled-Water Resistivity Versus Conductivity Data

Resistivity (Megohms/Centimeters)	Purity	Conductivity (Siemens/Centimeter)
10.0	} {	0.1
2.0	} Increasingly better {	0.5
1.0	} water purity {	1.0
0.5	} {	2.0
0.1	} {	10.0

The purity meter indication varies with ionized salt concentration and the temperature of the coolant flowing through the cell. The temperature effect is canceled by a built-in temperature compensation circuit.

The inlet conductivity is compared to a preset value of cell conductance to actuate an alarm circuit when the purity of the water drops below the preset level. In addition, the purity meter provides direct readings of the water purity at the inlet and the outlet of the demineralizer Typical operating requirements for the demineralizer are conductivity 1 micromho/cm at 77°F (resistivity 1 megohm/cm at 77°F), oxygen content 0.1 parts per million (ppm) by weight, and mechanical filtration 0.5 microns absolute.

When water has been circulated through the system for extended periods of time, a high-resistivity or low-conductivity reading may be indicated on both input and output samples. This condition is highly desirable and indicates that all ionizable material has been properly treated and that the demineralizer is maintaining a high degree of purity. When a system is filled with a fresh charge of water, it should be allowed to circulate for approximately 2 hours before comparing the input and output readings. During the initial circulation period, the resistivity readings vary because of the mixing action of water that has been treated by the demineralizer with the fresh charge of water.

A properly operating system can supply water of acceptable purity in 4 to 8 hours. Water in a system that has been secured for any length of time should be of acceptable purity within 2 hours. The resistivity or conductivity reading required for a specific installation must be maintained for optimum operation of the cooling water system.

The first indication of a problem in the demineralizer is usually indicated by abnormal purity meter readings (too low/high), an abnormal flowmeter reading, and/or alight and audible warning from the purity monitor. Some purity monitors can be tested for accuracy by a built-in test function on the meter to establish if the problem is in the purity monitor. If the purity monitor does not have a test feature, then use the calibration plug in place of one of the conductivity cells to test the operation of the purity meter. Most of the time, only routine maintenance is required to return the demineralizer to its normal operating condition.

Maintenance of the demineralizer consists primarily of the scheduled replacement of cartridges (before they are exhausted) and clogged filters. Obtaining satisfactory service life from the cartridges and filters is largely dependent on minimizing external contamination. Replacement cartridges must be kept sealed and stored in a cool, dry place until used. The circulating system must be kept tight to reduce the need for makeup water. Makeup water, in any case, should be as particle-free as possible and should not exceed 0.065 ppm chloride.

OXYGEN ANALYZERS

Oxygen analyzers are installed in some secondary cooling systems to measure the amount of dissolved oxygen in the liquid coolant. The presence of oxygen causes oxidation that leads to the formation of scale in the cooling system. An oxygen analyzer has an oxygen sensor installed in the supply side of the secondary cooling system.

The sensor is an electrolytic cell in an electrolyte solution or gel. The oxygen reacts with the electrolyte, causing a proportional change in the amount of current flow in the sensor. The sensor's electrical output is measured and displayed on the oxygen analyzer's meter, which is calibrated to read the oxygen content in parts per million or billion.

Because of the solid-state electronics and the few components used, the oxygen analyzer requires very little maintenance other than cleaning and changing the electrolyte in the sensor. When the meter on the analyzer requires frequent calibration because the meter readings are drifting or changing sharply, the analyzer has a bad sensor.

LIQUID-COOLING SYSTEM ALARM SWITCHBOARDS

The liquid-cooling system alarm switchboards (SWBDs) are installed in cooling systems to monitor various conditions to alert you to a problem that may develop in the cooling system. When an abnormal condition occurs, the alarm SWBD indicates the fault condition with both visual and audible alarms. The alarm SWBD usually has several remote bells and lights in the combat information center (CIC) and other electronic spaces aboard ship to indicate that a fault condition has occurred.

The alarm SWBD is in the CIC or the coolant pump room. There are several standard types of alarm switchboards used throughout the Navy.

A common type of alarm SWBD is shown in figure 2-22.

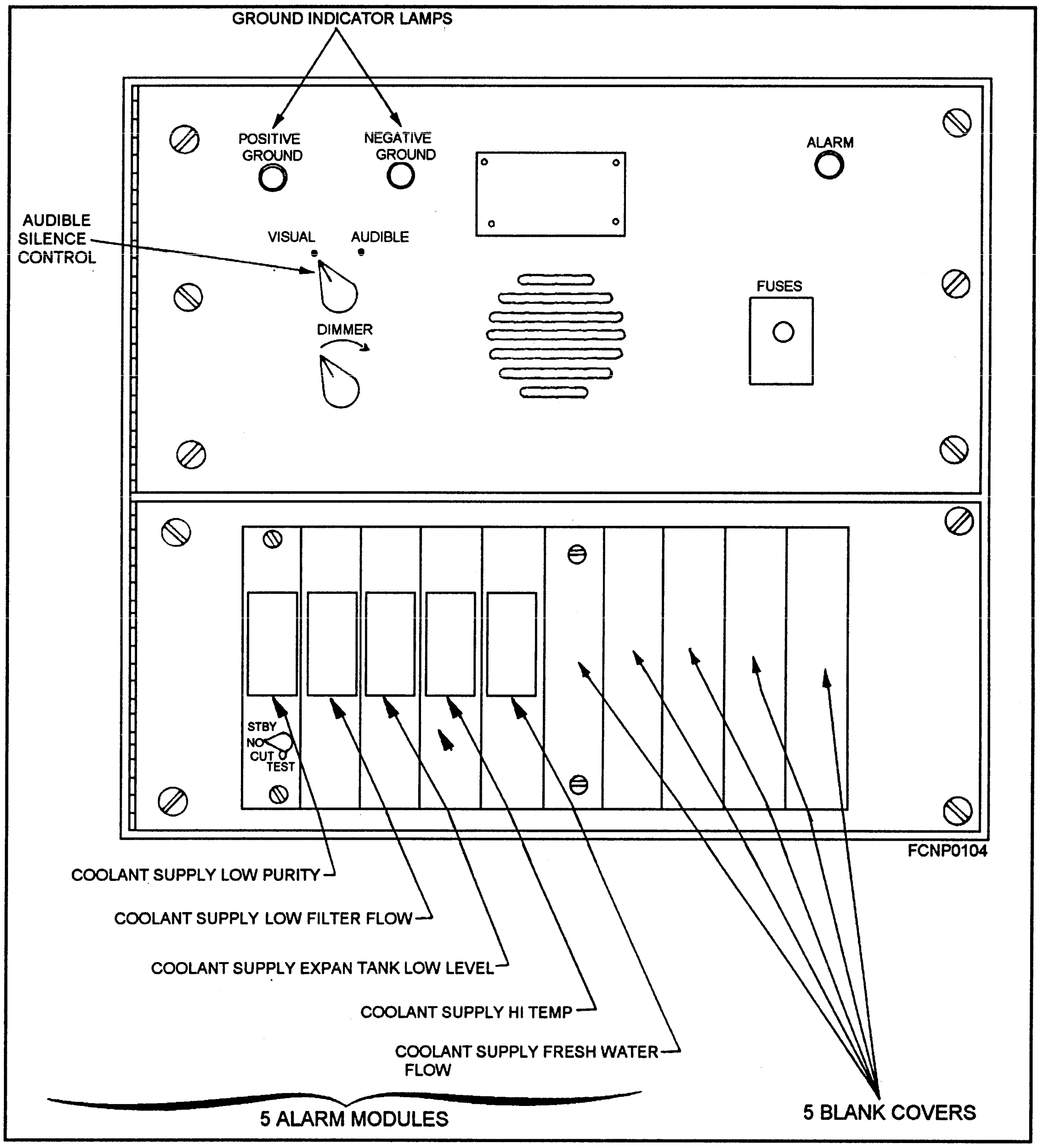

Figure 2-22.—Liquid-cooling system alarm switchboard.

On the main alarm panel, there are two ground indicator lamps to indicate the presence of a ground in the alarm system. All shipboard alarm panels and remote sensors are electrically isolated from the ship's ground. The only exception is the ground fault detector, which is connected to ground for ground monitoring.

If one or both lamps light, you should have the alarm SWBD and its remote sensors serviced by an electrician who has maintenance responsibility for removing a very dangerous shock hazard. The AUDIBLE silence control is a two-position switch that permits silencing (VISUAL position) the audible alarm on the main panel. The ALARM lamp on the main panel is lighted when the AUDIBLE silence control is placed in the VISUAL position, and the system is in an alarm condition.

The lower half of the alarm panel holds the alarm modules that are connected through the alarm panel to the remote sensors. If additional remote sensors are installed at a later date, a new alarm module is plugged into the lower panel for each sensor installed. Each alarm module includes a center-divided lighted display. Either half can independently display a steady red light, a flashing red light, or no light, depending on the circuit logic.

The six possible combinations of alarm module lights and the appropriate audible alarm are shown in figure 2-23.

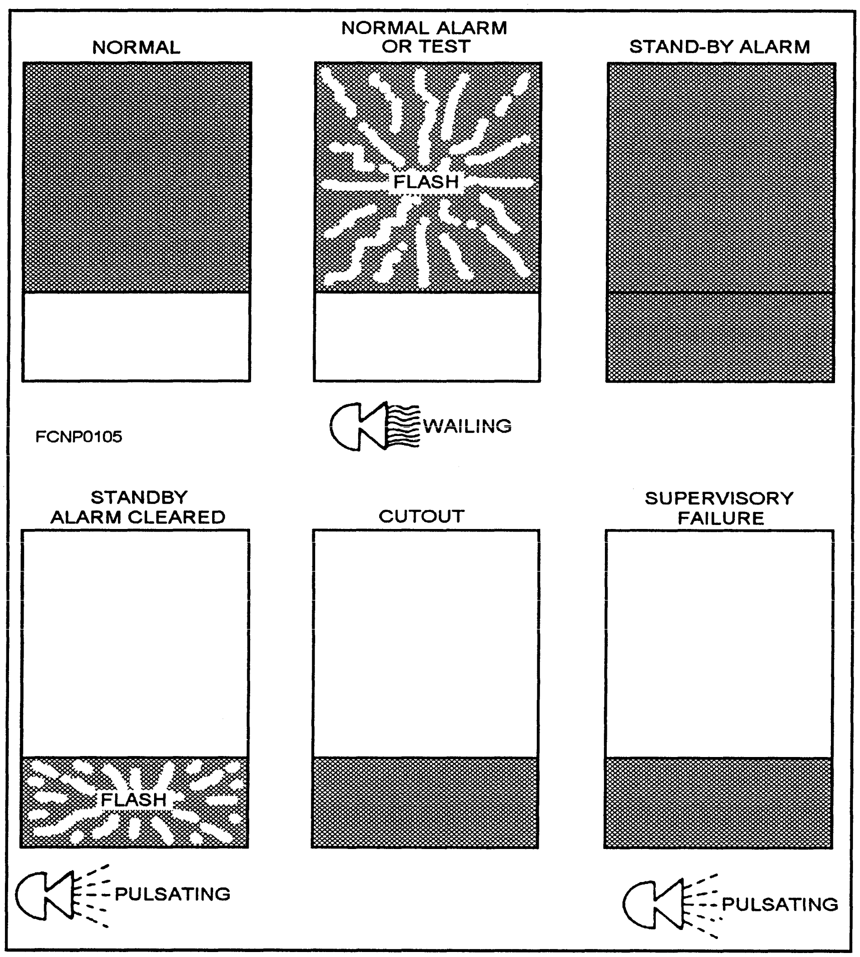

Figure 2-23.—Alarm switchboard visual displays and audible outputs.

On the lower half of each alarm module is a four-way position switch that allows you to place the individual alarm module in the following modes:

- **NORMAL:** This is the normal operation mode. With the sensor contacts open, the upper indicator lamp in the module is on steady while the lower lamp is off. If an alarm condition occurs, the sensor contacts will close; the upper lamp will then flash while the lower lamp remains off and an alarm command from the module actuates atone generator, producing a wailing alarm. If the sensor loop is open-circuited, with the selector switch in the NORMAL position, the alarm module will signal a supervisory failure. In this case, the upper lamp will be off while the lower lamp will be steadily on, and the tone generator will come on, producing a pulsating alarm.

- **STANDBY:** This is the position for acknowledging an alarm. If the selector switch is moved from the NORMAL to the STANDBY position during an alarm condition, both the upper and lower indicator lamps will be steadily on and the audible alarm will be silenced. When the alarm condition is cleared with the selector switch in the STANDBY position, the lower lamp will change to a flashing mode and the upper lamp will go out. Also, the command will be fed to the tone generator, producing a pulsating alarm.

- **CUTOUT:** With the selector switch in the CUTOUT position, the upper lamp is out while the lower lamp is steadily on. In this position, power is removed from the sensor loop to facilitate maintenance.

- **TEST:** The TEST selector switch position simulates an alarm condition. The upper indicator lamp flashes while the lower lamp is off, producing a wailing alarm.

LIQUID-COOLING SYSTEM MAINTENANCE RESPONSIBILITY

The most important responsibility that you have as a Fire Controlman that will extend the life of the liquid-cooling system components and increase the reliability of the cooling system is how you perform preventive and corrective maintenance according to the PMS. Properly performed preventive maintenance drastically reduces the amount of corrective maintenance necessary. When cooling systems are neglected, they deteriorate very quickly. To restore the cooling system to its proper performance, you may have to undertake extreme and costly repairs.

The PMS responsibility of the cooling system varies from one system to another. On some systems, the engineering department has the total responsibility of preventive and corrective maintenance. On other systems, you will share the maintenance responsibility jointly with the engineering department. In these situations, the Fire Controlman will probably perform the preventive maintenance, and the engineers will perform the corrective maintenance on major components.

When assigned the responsibility for maintaining the cooling system, you should perform the preventive maintenance in accordance with the maintenance requirement cards (MRCs) for that equipment to maximize the operation of the cooling system.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Basic Liquid Cooling Systems for Shipboard Electronics, NAVSEA 0948-LP-122-8010, Naval Sea Systems Command, Washington, DC, 1977.

All systems operating procedures that describe troubleshooting techniques and procedures applicable to each FCs on your ship class.